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इस्तेमाल भूवस्त्रादि — विशिष्टि

**Geosynthetics — Geotextiles Used
in Subsurface Drainage Application
— Specification**

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FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Geosynthetics Sectional Committee had been approved by the Textile Division Council.

Control of water is critical to the performance of buildings, pavements, embankments, retaining walls and other structures. Drains are used to relieve the hydrostatic pressure against underground and retaining walls, slabs and underground tanks and to prevent loss of soil strength and stability in slopes, embankments and beneath pavements. In transportation applications, if the base course does not drain rapidly enough, stress from the traffic loadings is transferred to the subgrade with little or no reduction, resulting in accelerated road failure. The removal of water shall be performed in a controlled fashion. Otherwise, severe erosion, piping, or settlement of soils may result in undermining adjacent structures. To accomplish this task the drainage system should fulfill two criteria:

- a) Have maintained permeability by providing relatively unimpeded flow of water; and
- b) Filtration of base soil by preventing the migration of soil fines into the drain.

These criteria can be met by using several layers of specially graded aggregates. This often proves to be extremely expensive requirement to meet. The same result can be achieved at a fraction of the cost by using selected geotextiles, which act as filters around the aggregate drainage system. The introduction of geotextile lined drainage systems has enhanced the technical benefits and economical application of blanket and trench drains under and adjacent to pavement structures. The excellent filtration and separation characteristics associated with geotextiles permits the use of a single layer of open graded aggregate base or trench aggregate enveloped in a geotextile.

The stability of the subgrade soils depends on groundwater table. Some clay soils can swell or shrink as their water content increases or decreases, respectively. Also, most soils are considerably weaker when they have high water contents or have not been drained prior to loading. This means that weather-related or seasonal fluctuations in groundwater levels can adversely affect permanent structures founded on undrained soils. Therefore, draining the saturated soils can increase their strength and stability. The lower the permeability of the subgrade soils, the closer together the drainage layers/zones shall be to provide effective dewatering.

The traditional methods of subgrade dewatering by digging a trench or providing a coarse aggregate drainage layer or a pipe system or use of fine sand as a filter are time consuming and costly and provide inconsistent properties. Geotextiles are being used in lieu of select grades of sand for effective dewatering to accept seepage and act as properly graded filter to prevent piping of subgrade soil because they are less expensive, provide more consistent properties and are much easier to install. Geotextiles have been used in toe drains of embankments where they are easily accessible if maintenance is required and where malfunction can be detected.

The excellent filtration and separation characteristics associated with filtration geotextiles permits the use of a single layer of an open graded base or trench aggregate enveloped in a geotextile. The thin filtration geotextile reduces the required excavation as well as the cost of the drained structural section. The increase in service life of flexible pavements by 25 percent and that of rigid pavements by 50 percent has been identified by use of an efficient functioning edge drain system using geotextile.

Filtration and separation fabrics are non-woven or woven polypropylene or polyester fabrics with specified strength characteristics used as permeable separators to restrain soil or other particles subjected to hydrodynamic forces while allowing the passage of fluids into or across a geotextile and to prevent inter-migration of adjacent soil layers of vastly different particle sizes and particle distributions. The primary geotextile characteristics influencing filter functions are opening size (as related to soil retention), flow capacity and clogging potential which are indirectly measured by the apparent opening size, permittivity and gradient ratio test. The geotextile shall also have the strength and durability to survive construction and long-term conditions for the design life of the drain. Additionally, construction methods have a critical influence on geotextile drain performance.

(Continued to Third Cover)

Indian Standard

GEOSYNTHETICS — GEOTEXTILES USED IN SUBSURFACE DRAINAGE APPLICATION — SPECIFICATION

1 SCOPE

1.1 This standard specifies requirements for two classes of geotextiles used in drainage application such as subgrade dewatering, road base drainage and structure drainage by placing the geotextile against the soil to allow long-term passage of water into a subsurface drain system retaining the *in-situ* soil.

1.1.1 Class 1 geotextiles are for applications where applied stresses are more severe, that is, very coarse shape angular aggregate is used, compaction is greater than 95 percent of maximum density as per IS 2720 (Part 15) or depth of trench is greater than 300 mm.

1.1.2 Class 2 geotextiles are suitable for drainage applications which are less severe, that is, smooth graded surfaces having no sharp angular aggregate, compaction is less than or equal to 95 percent of maximum density as per IS 2720 (Part 15).

1.2 Woven slit film geotextiles (that is, geotextiles made from yarns of a flat, tape-like character) shall not be used.

NOTES

1 The function of the drainage in this application refers to including a tensile member in the form of a geotextile against soil to protect coarse aggregate drains or used as a geotextile sandwiched aggregate blanket or as a three dimensional plastic drainage core wrapped with a filtration geotextile.

2 The primary function of the geotextile is filtration. Geotextile filtration properties are a function of the *in-situ* soil gradation, plasticity and hydraulic conditions.

3 This is a material purchasing specification and design review of its use for intended applications is recommended. This is not a construction or design specification. Subsurface drainage is a site specific design issue which should be addressed by the engineers responsible for the drainage structure design. Design details for geotextile for subsurface drainage, such as geotextile type, structure and associated details, shall be as shown on the contract drawings.

4 This standard is based on the minimum requirements of the geotextile to provide drainage, filtration and survivability from installation stress. In general, the geotextile shall be placed at the proper elevation, location and orientation as detailed on the plans and specification.

2 REFERENCES

The standards listed in Annex A contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are

subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated in Annex A.

3 DEFINITIONS

For the purpose of this standard the following definitions and those given in IS13321 (Part 1) shall apply.

3.1 Minimum Average Roll Value (MARV) — The average value of roll minus two standard deviations. Statistically, it yields a 97.7 percent degree of confidence that any sample taken during quality assurance testing will exceed value reported.

3.2 Subgrade Improvement — It is defined as the improvement of the bearing capacity and mitigation of deformation of the subgrade soil by placing a geotextile immediately over a soft subgrade soil. The goal of this application may be to reduce undercut requirements, improve construction efficiency, reduce the amount of aggregate subbase/base material required, provide a stiff working platform for pavement construction, or combination of these.

3.3 Filtration — The long-term free flow of water from the subgrade through the geotextiles into a subsurface drain system retaining the *in-situ* soil solid particles.

4 REQUIREMENTS

4.1 The geotextiles used in subsurface drainage applications shall be inert to commonly encountered chemicals, resistant to rot and mildew, and shall have no tears or defects which adversely affect or alter its physical properties.

4.2 Polymers used in the manufacture of geotextiles, and the mechanical fasteners or threads used to join adjacent rolls, shall consist of long chain synthetic polymers, composed of at least 95 percent by weight of polyolefins, polyesters or polyamides when tested as per dissolution method in respective solvents as specified in IS 667. They shall be formed into a stable network such that the ribs, filaments or yarns retain their dimensional stability relative to each other, including selvages. Recycled polyester shall not be used in the manufacture of geotextiles and only virgin polyester shall be used for manufacture of polyester

containing geotextiles. The isophthalic acid content of the virgin polyester shall be nil when tested according to the method prescribed in Annex B.

4.3 Geotextiles shall be dimensionally stable and able to retain their geometry under manufacture, transport and installation. Woven slit film geotextiles (that is, geotextiles made from yarns of a flat, tape-like character) shall not be used. Geotextiles used as a filtration and drainage material shall conform to the requirements specified in Table 1. Average of test results from any sampled roll in a lot shall meet or exceed the minimum values noted herein.

NOTES

1 All numeric values given in Table 1 except Apparent Opening Size (AOS), represent MARV in the weakest principal direction. Values for AOS represent maximum average roll values.

2 The property values in Table 1 represent default values which provide for sufficient geotextile reinforcement and survivability under most construction conditions.

5 SAMPLING AND CRITERIA FOR CONFORMITY

5.1 Lot

The quantity of the same class of geotextile manufactured from the same polymer under identical conditions and supplied to a buyer against one dispatch note shall constitute a lot.

5.2 Sampling for tests shall be done in accordance with IS 14706 from each lot. Acceptance shall be based on testing of conformance samples obtained using procedure given in IS 14706.

5.3 Testing of samples shall be performed in accordance with the methods referred to in this standard for the indicated requirement(s). The number of specimens to test shall be as specified in each test method. Product acceptance shall be determined by comparing the average test results of all the specimens within a given sample to the specified MARV.

5.4 Criteria for Conformity

The geotextile shall be tested for all the requirements as specified in Table 1 and **4.1** to **4.3** of this standard. When any individual sample fails to meet any specification requirement, that roll shall be rejected and two additional sample rolls shall be selected from the same lot. The lot shall be declared conforming to the requirements of this standard if neither of these two additional samples fails to comply with any part of this standard, otherwise the entire quantity of rolls represented by that sample shall be rejected.

6 MARKING AND LABELLING

6.1 The geotextile material shall be marked with the following by attaching the printed labels:

- a) Identification of the geotextile material as per manufacturer's recommendation, for example, polyester multifilament woven geotextile for subsurface drainage;
- b) Class of geotextile material, that is Class 1 or Class 2;
- c) Batch No., lot number and roll number;
- d) Date of manufacture of geotextile material;
- e) Any other information/instruction prescribed by the manufacturer or by the law in force;
- f) Manufacturer's name, initials or trade-mark; and
- g) The country of origin.

6.2 BIS Certification Marking

The geotextile may also be marked with the Standard Mark.

6.2.1 The use of the Standard Mark is governed by the provisions of *Bureau of Indian Standards Act, 1986* and the Rules and Regulations made thereunder. Details of conditions under which a licence for the use of the Standard Mark may be granted to manufacturers or producers, may be obtained from the Bureau of Indian Standards.

7 PACKING

The geotextile shall be packed in rolls or as per the contract or order. Each roll or package shall be protected by wrapping it in a LDPE film of minimum thickness of 40 microns to prevent it from the adverse impact of heat and moisture, oil, grease, dirt, dust and other stains during shipment and storage prior to deployment.

8 INFORMATION AND SAMPLES TO BE SUBMITTED BY THE MANUFACTURER

8.1 The manufacturer shall submit to the purchaser the following:

- a) Geotextile product sample approximately one square meter or larger;
- b) Geotextile product data sheet and certification from himself or by third party certification such as the use of the Standard Mark stating that the geotextile product supplied meets the requirements of this standard; and
- c) Manufacturer's installation instructions and general recommendations.

9 STORAGE AND PROTECTION

9.1 During storage, elevate the geotextile rolls off the ground and adequately protect them from the following:

- a) Site construction damage;
- b) Excessive precipitation;
- c) Extended exposure to sunlight;
- d) Aggressive chemicals;
- e) Flames or temperatures in excess of 71°C;
- f) Excessive mud, wet concrete, epoxy, or other deleterious materials coming in contact with and affixing to the geotextile material; and
- g) Any other environmental condition that may damage the physical property values of reinforcement.

9.2 Store the geotextile material at temperatures above –20°C.

9.3 Lay the rolled materials flat or vertical on ends.

9.4 Do not leave the geotextile material directly exposed to sunlight for a period longer than the period recommended by the manufacturer.

9.5 Each geotextile roll shall be wrapped with a material that will protect it from damage due to shipment, water, sunlight and contaminants.

9.6 Keep geotextile dry until installation, and do not store directly on the ground.

Table 1 Requirements of Geotextiles for Subsurface Drainage Applications

(Clauses 4.3 and 5.4)

Sl No.	Characteristic(s)	Requirement(s)				Method of Test, Ref to
		Class 1		Class 2		
		Elongation < 50 percent	Elongation ≥ 50 percent	Elongation < 50 percent	Elongation ≥ 50 percent	
		(3)	(4)	(5)	(6)	
(1)	(2)					(7)
A. Index Properties						
i) Type of geotextile		← Woven/non-woven →		← Woven/non-woven →		—
ii) Roll length, m, <i>Min</i>		← 50 or 100 or as agreed →		← 50 or 100 or as agreed →		IS 1954
iii) Roll width, m, <i>Min</i>		← 2.0 or 5.0 or as agreed →		← 2.0 or 5.0 or as agreed →		IS 1954
iv) Grab strength, N, <i>Min</i>		1 100	700	800	500	IS 16342
v) Sewn seam strength, N, <i>Min</i>		990	630	720	450	IS 15060
vi) Trapezidal tear strength, N, <i>Min</i>		400	250	300	180	IS 14293
vii) CBR puncture strength, N, <i>Min</i>		400	250	300	180	IS 16078
viii) Burst strength, kPa, <i>Min</i>		2 700	1 300	2 100	950	IS 1966 (Part 2)
B. Structural Integrity Properties						
i) <i>In-situ</i> soil passing 0.075 mm sieve (200 mesh sieve), Percent						IS 1670
a) Course		← < 15 →		← < 15 →		IS 14324
b) Medium		← 15 - 50 →		← 15 - 50 →		
c) Fine		← > 50 →		← > 50 →		
ii) Permittivity, sec ⁻¹ , <i>Min</i>						IS 14324
a) Course		← 0.5 →		← 0.5 →		IS 14294
b) Medium		← 0.2 →		← 0.2 →		
c) Fine		← 0.1 →		← 0.1 →		
iii) Apparent opening size (AOS), mm, <i>Max</i>						IS 14294
a) Course		← 0.43 →		← 0.43 →		IS 13162 (Part 2)
b) Medium		← 0.25 →		← 0.25 →		
c) Fine		← 0.22 →		← 0.22 →		
C. Durability Properties						
i) Pullout interaction coefficient, at 6 mm displacement, Normal load = 5 kPa, <i>Min</i> (see Notes 1 and 2)		← 0.8 →		← Not applicable →		IS 16380
ii) Coefficient of direct shear at peak geotextile shear strength, Normal load = 5 kPa, <i>Min</i> (see Notes 3 and 4)		← 5 →		← Not applicable →		Annex C
iii) Resistance to installation damage, percent retained strength, SC/SW/GP (see Note 5), <i>Min</i>		← 95/93/90 →		← 95/93/90 →		ISO 10722
iv) Ultraviolet stability at 500 h, retained strength, percent of original strength, <i>Min</i>		70	—	70	—	IS 13162 (Part 2)

NOTES

1 The coefficient of interaction, C_i , is the ratio between the average shear stress on the geosynthetic specimen in the pullout test and the mobilized shear stress in the fill material in direct shear tests under the same confining stress and shall be calculated as follows:

$$C_i = \frac{F_p}{2LW(\sigma_n \tan \phi + c)}$$

where

- C_i = coefficient of interaction,
 F_p = measured pullout force,
 L = initial length of the geosynthetic specimen,
 W = initial width of the geosynthetic specimen,
 σ_n = applied normal stress,
 ϕ = friction angle of the fill material, and
 c = cohesive intercept of the fill material.

2 For pullout interaction coefficient test, rate of displacement may be increased to 125 mm/min. A graded angular base material as described in Table 2 shall be used in laboratory testing test sample shall be at least 0.3 m in length and 0.3 m in width.

3 For coefficient of direct shear test, rate of displacement may be increased to 50 mm/min. A graded angular base material as described in Table 2 shall be used in laboratory testing. Test sample shall be at least 0.3 m in length and 0.3 m in width.

4 The coefficient of direct shear shall be determined using the peak geotextile shear strength with the shear strength of the graded angular base measured at the same displacement as the peak geotextile shear strength.

5 Resistance to installation damage (loss of load capacity or structural integrity) when subjected to mechanical installation stress in clayey sand (SC), well graded sand (SW) and crushed stone classified as poorly graded gravel (GP).

6 Class 2 geotextile may be specified for trench drain application based on field experience, laboratory testing and visual inspection of a geotextile sample removed from a field test section or when the subsurface drain depth is less than 2 m and drain aggregate is less than 30 mm.

7 In addition to the above default filtration property value of permittivity and AOS, site specific geotextile design may be performed if one or more of the following problematic soil environment is encountered: unstable or highly erodible soils such as non-cohesive silts, gap graded soils, alternating sand/silt laminated soils, dispersive clays and/or rock flour.

Table 2 Gradation of Base Material for Determining the Coefficient of Interaction and Direct Shear (Sliding)

(Note 1 and 2 under Table 1)

SI No. (1)	Sieve Size, mm (2)	Percent Passing (3)
i)	37.5	100
ii)	25	95 – 100
iii)	19	60 – 100
iv)	4.75	30 – 60
v)	0.425	10 – 30
vi)	0.075	3 – 10

NOTE — LL < 30 and PI < 10

ANNEX A

(Clause 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	Title	IS No.	Title
667 : 1981	Methods for identification of textile fibres (<i>first revision</i>)	14293 : 1995	Geotextiles — Method of test for trapezoid tearing strength
1670 : 1977	Methods for test sieving (<i>first revision</i>)	14294 : 1995	Geotextiles — Method for determination of apparent opening size by dry sieving technique
1954 : 1990	Determination of length and width of woven fabrics — Methods (<i>second revision</i>)	14324 : 1995	Geotextiles — Methods of test for determination of water permeability-permittivity
IS 1966 (Part 2) : 2009/	Textiles — Bursting properties of fabrics — Determination of bursting strength and bursting distension: Part 2 Pneumatic method (<i>second revision</i>)	14706 : 1999	Geotextiles — Sampling and preparation of test specimens
ISO 13938-2 : 1999		15060 : 2001/	Geotextiles — Tensile test for joints/seams by wide-width method
2720 (Part 15) : 1965	Methods of test for soils: Part 15 Determination of consolidation properties (<i>first revision</i>)	ISO 10321 : 1992	
6359 : 1971	Method for conditioning of textiles	IS 16078:2013	Geosynthetics — Static puncture test (CBR test)
13162 (Part 2) : 1991	Geotextiles — Methods of test: Part 2 Determination of resistance to the exposure of ultraviolet light and water (xenon-arc type apparatus)	IS 16342:2015	Geosynthetics — Method of test for grab breaking load and elongation of geotextiles
13321 (Part 1) : 1992	Glossary of terms for geosynthetics: Part 1 Terms used in materials and properties	IS 16380 : 2015	Geosynthetics — Method of test for measuring geosynthetic pullout resistance in soil

ANNEX B

(Clause 4.2)

METHOD OF TEST FOR ISOPHTHALIC ACID CONTENT OF THE VIRGIN POLYESTER FIBRE

B-1 PRINCIPLE

This method is applicable to measure isophthalic acid content in polyethylene terephthalate sample. The polymer sample is digested in benzyl alcohol, depolymerized then esterified to dibenzyl isophthalate, dibenzyl terephthalate and glycol's. Isopropyl titanate is added as a depolymerization catalyst. The sample is analyzed by gas chromatography and the peak areas of the two esters are used to estimate the weight percentage dimethyl isophthalate using an internal standard.

B-2 POTENTIAL ENVIRONMENT ISSUE

B-2.1 In case of spillage, it can lead to pollution near the workplace area and environment hazard. After analysis sample is disposed as per laid down procedure.

B-2.2 Hydrogen, nitrogen and instrument air are used during analysis. The hydrogen gas has no adverse ecological effects are expected. Hydrogen does not contain any Class I or Class II ozone depleting chemicals. However hydrogen is explosive. Gaseous nitrogen is an inert non- flammable gas. High concentration in air may cause deficiency of oxygen with the risk of unconsciousness and death. Chloroform in high concentration in air can kill most animals in few minutes.

B-3 POTENTIAL SAFETY, OCCUPATIONAL HEALTH ISSUES

B-3.1 Proper PPE's like safety goggles, apron, surgical hand gloves to be used.

B-3.2 Glassware is to be handled with care.

B-3.3 Leak check to be carried out while handling of gas cylinder.

B-3.4 Glassware is to be handled with care.

B-3.5 Inhalation of chloroform causes dilation pupils with reduced reaction to light as well as reduced intraocular pressure. Irritation of mucous membrane, conjunctiva. If contacted with skin and eyes cause irritation. Seek medical advice if inhaled.

B-3.6 Use leather hand gloves while handling hot apparatus and equipments.

B-4 APPARATUS

B-4.1 Gas Chromatograph (GC), with flame ionization detector.

B-4.2 Capillary Column, 60 m length and 0.53 mm ID MXT® - 1

B-4.3 Dispensette or Pipette, 2 ml, 5 ml and 10 ml.

B-4.4 Volumetric Flask, 100 ml, 500 ml.

B-4.5 Beaker

B-4.6 Funnel

B-4.7 50 ml Flask

B-4.8 Heating Mantle, to maintain temperature of 250°C

B-4.9 AR Grade Dimethyl Isophthalate (DMI)

B-4.10 AR Grade Benzyl Alcohol

B-4.11 AR Grade Chloroform

B-4.12 AR Grade Isopropyl Titanate

B-4.13 AR Grade Dimethyl Suberate

B-5 PREPARATION OF STANDARD SOLUTIONS

B-5.1 Stock Dibenzyl Suberate (Internal Standard) Solution

Take 1.0 ± 0.01 g of dimethyl suberate (DMS). Add 100 ml of benzyl alcohol and 6 to 7 drops of isopropyl titanate digest it for 2 h. Allow it to cool up to room temperature then make the volume to 500 ml by carefully rinsing the flask by isopropyl alcohol. Dimethyl suberate will get converted into dibenzyl suberate (DBS). Mark the stock solution as DBS per $2\text{ml} \approx X \cdot XXXX \text{ mg}$

B-5.2 Stock Dimethyl Isophthalate (DMI) Solution

Take 0.2 ± 0.01 g of dimethyl isophthalate (DMI). Add 40 ml of benzyl alcohol and 6 to 7 drops of isopropyl titanate digest it for 2 h. Allow it to cool up to room temperature then make the volume to 100 ml by carefully rinsing the flask by isopropyl alcohol. This will be converted to dibenzyl isophthalate (DBI). Mark the stock solution as DBI per $2 \text{ ml} \approx X \cdot XXXX \text{ mg}$.

B-5.3 Standard Solution for Response Factor

Take 2 ml of solution prepared in B-5.1 and 2 ml of solution prepared in B-5.2. Add 10 ml of chloroform.

B-5.4 2.0 Percent Standard IPA Stock Solution

Weigh out accurately 0.200 ± 0.005 g of pure DMI powder into round bottom flask, add 30 ml of benzyl alcohol and 3 drops of isopropyl titanate, reflux the solution for 5 h reagent and dilute to 100 g by isopropyl alcohol, calculate actual DMI concentration by considering its purity and label the flask with actual weight taken. Consider this weight during calculation of IPA by GC.

B-5.5 2.0 Percent Standard IPA Solution for GC Injection

Take 2.0 ml IPA stock solution and add 2 ml internal standard (*see B-5.1*) and further add 10 ml of chloroform, same bottle to be labelled as 2.0 percent IPA Inject 1 μ l in GC.

B-6 CALIBRATION FOR PERFORMANCE CHECK – TWICE /MONTH STANDARD CHIPS**B-7 ANALYTICAL PROCEDURE**

Inject 1 μ l of standard solution for response factor (*see B-5.3*) and calculate response factor. Inject 1 μ l of 2 percent standard IPA solution. If value of 2.0 percent standard IPA solution is varying in the range of 0.01 percent, then there is no need for change in response factor. If there is deviation in value then rerun standard solution for response factor (*see B-5.3*). Weight 0.2 ± 0.02 g of chips into the round bottom flask. Add 2 ml of benzyl alcohol. Add 3 drops of isopropyl titanate. Digest the solution for 1 h. Allow it to cool up to room temperature. Add 10 ml of chloroform. Add 2 ml of internal standard solution that is solution prepared

in **B-5.1** and shake vigorously. Inject 1 μ l of sample solution into gas chromatograph.

B-8 CHROMATOGRAPH SETTINGS

Injector temperature	: 300°C
Detector temperature	: 320°C
Oven temperature	: 270°C
Gas flow rates	
Nitrogen	: 20 psig
Hydrogen	: 30 ± 10 ml/min
Air	: 300 ± 20 ml/min
Attenuation	: – 4
Range	: 1

B-9 CALCULATION

$$\text{Response factor (RF)} = \frac{A_1 \times W_2}{A_2 \times W_1}$$

where

A_1 = area of dibenzyl suburate (DBS) (internal standard) solution;

W_1 = weight of DBS in solution, in mg;

A_2 = area of DBI in standard solution; and

W_2 = weight of DBI in standard solution, in mg.

$$\text{Percent IPA} = \frac{\text{RF} \times \text{mg Internal Standard} \times \text{Area of IPA in sample} \times 100}{\text{Weight of sample, in mg} \times \text{Area of internal standard in sample}}$$

ANNEX C

(Clause 4.3 and Table 1)

METHOD OF TEST FOR DETERMINING THE COEFFICIENT OF SOIL AND
GEOSYNTHETIC FRICTION BY THE DIRECT SHEAR

C-1 PRINCIPLE

C-1.1 The shear resistance between a geosynthetic and a soil, or other material selected by the user, is determined by placing the geosynthetic and one or more contact surfaces, such as soil, within a direct shear box. A constant normal force representative of design stresses is applied to the specimen, and a tangential (shear) force is applied to the apparatus so that one section of the box moves in relation to the other section. The shear force is recorded as a function of the horizontal displacement of the moving section of the shear box.

C-1.2 The test is performed at a minimum of three different normal stresses, selected by the user, to model appropriate field conditions. The limiting values of shear stresses are plotted against the applied normal compressive stresses used for testing. The test data are generally represented by a best fit straight line whose slope is the coefficient of friction between the two materials where the shearing occurred. The y-intercept of the straight line is the adhesion.

C-2 APPARATUS

C-2.1 Shear Device — A rigid device to hold the specimen securely and in such a manner that a shear force without torque can be applied to the specimen. The device consists of both a stationary and moving container, both of which are capable of containing dry or wet soil and are rigid enough to not distort during shearing of the specimen. The travelling container shall be placed on firm bearings and rack, or other mechanism, to ensure that the movement of the container encounters low friction and is only in a direction parallel to that of the applied shear force.

NOTE — The position of one of the containers should be adjustable in the normal direction to compensate for deformation of the substrate and geosynthetic. The container should also be aligned to minimize any moment produced by non-colinear forces on the containers.

C-2.1.1 Square or rectangular containers are recommended and they should have a minimum dimension that is the greater of 300 mm, 15 times the d_{85} of the coarser soil used in the test, or a minimum of five times the maximum opening size (in plan) of the geosynthetic tested. The depth of each container that contains soil shall be a minimum of 50 mm or six times the maximum particle size of the coarser soil tested, whichever is greater.

NOTE — d_{85} is the equivalent grain diameter (mm) at which 85 percent of the soil is finer by weight.

C-2.2 Normal Stress Loading Device, capable of applying and maintaining a constant uniform normal stress on the specimen for the duration of the test. Careful control and accuracy (62 percent) of the normal stress is important. Normal stress loading devices include, but are not limited to, weights, pneumatic or hydraulic bellows, or piston-applied stresses. For jacking systems, the tilting of loading plates shall be limited to 2° from the shear direction during shearing. The device shall be calibrated to determine the normal stress delivered to the shear plane.

C-2.3 Shear Force Loading Device, capable of applying a shearing force to the specimen at a constant rate of displacement in a direction parallel to the direction of travel of the moving container. The horizontal force measurement system shall be calibrated, including provisions to measure and correct for the effects of friction and tilting of the loading system. The rate of displacement shall be controlled to an accuracy of 610 percent over a displacement range of at least 6.35 mm/min to 0.025 mm/min. The system shall allow constant measurement and readout of the shear force applied. An electronic load cell or proving ring arrangement is generally used. The shear force loading device should be connected to the test apparatus in such a fashion that the point of the force application to the traveling container is in the plane of the shearing interface and remains the same for all tests.

C-2.4 Displacement Indicators, for providing readout of the horizontal shear displacement and, if desired, vertical displacement of the specimen during the consolidation or shear phase.

Displacement indicators such as dial indicators, or linear variable differential transformers (LVDT), capable of measuring a displacement of at least 75 mm for horizontal displacement and 25 mm for vertical displacement are recommended. The sensitivity of displacement indicators should be 0.02 mm for measuring horizontal displacement.

C-2.5 Geosynthetic Clamping Devices, required for fixing geosynthetic specimens to the stationary section or container, the travelling container, or both, during shear. Clamps shall not interfere with the shearing surfaces within the shear box and shall keep the

geosynthetic specimens flat during testing. Flat jaw-like clamping devices are normally sufficient. Textured surfaces or soil shall be used to support the top and/or bottom of the geosynthetic. These surfaces shall permit flow of water into and out of the test specimens. Selection of the type of texture surface should be based on the following criteria:

C-2.5.1 The gripping surface shall be able to prevent the outside surface of the geosynthetic being sheared from slipping to the extent that the geosynthetic fails.

C-2.5.2 The gripping surface shall be able to completely transfer the shear stress through the outside surfaces into the geosynthetic.

C-2.5.3 The gripping surface shall not damage the geosynthetic and should not influence the shear strength behaviour of the geosynthetic.

C-2.6 Soil Preparation Equipment, for preparing or compacting bulk soil samples.

C-2.7 Miscellaneous Equipment, as required for preparing geosynthetic specimens. A timing device and equipment required for maintaining saturation of the geosynthetic or soil samples, if desired.

C-3 GEOSYNTHETIC SAMPLING

C-3.1 Take a minimum of three specimens for shearing in a direction parallel to the machine (or roll) direction of the laboratory sample and three specimens for shearing in a direction parallel to the cross-machine (cross-roll) direction. The specimens should be sufficiently large to fit snugly in the container described in **C-2.1.1** and they should be of sufficient size to facilitate clamping. All specimens should be free of surface defects, etc. Take no specimens nearer the selva or edge of the geosynthetic production unit than 1/10 the width of the unit.

C-4 CONDITIONING

C-4.1 Bring the specimens to moisture equilibrium in the atmosphere for testing textiles as specified in IS 6359.

C-5 PROCEDURE

C-5.1 Place soil or rigid substrate in the lower container, as required. Compact the soil at the specific moisture content to the density desired. If soil is used, fill the lower container with soil so that the surface of the soil specimen protrudes a distance equal to one-half of the d_{85} of the soil. A protrusion of 1 mm is sufficient for fine-grained soils. Level the soil surface carefully.

C-5.2 Place the geosynthetic specimen loosely over the substrate. Remove all folds and wrinkles in the

geosynthetic. Clamp or otherwise fix the end of the specimen temporarily, and reset it to ensure that the geosynthetic specimen is in complete contact with the soil. Verify that the protrusion of the soil substrate is suitable as outlined in **C-5.1**.

C-5.3 Fix the two halves of the shear box in the start position. Clamp or fix the upper half of the shear box so that it cannot move during the next step of preparation.

C-5.4 Place the upper substrate or soil at the desired density and moisture content in a manner that minimizes damage to the geosynthetic specimen. Apply the seating normal stress.

C-5.4.1 Apply the normal seating load.

C-5.4.2 If the seating load does not equal the normal load for testing, apply the normal load for testing and monitor the vertical displacements until the sample comes to equilibrium. Verify that equilibrium is reached before proceeding.

C-5.4.3 After the consolidation period, reclamp the geosynthetic specimen to the upper or lower container, as required.

C-5.5 Place the displacement indicators and assemble the shear loading device. Create a gap between the upper box and lower box. The gap should be large enough to prevent friction between the boxes during shear but small enough to prevent soil particles from entering into the gap and creating friction. If necessary, adjust the location of the horizontal loading ram to minimize the induced moment.

C-5.6 Apply the shear force at a rate of 1 mm/min.

C-5.7 Record the shear force as a function of horizontal displacement. Record a minimum of 50 data points per test.

C-5.8 Run the test until the applied shear force remains constant with increasing displacement. Displacements ranging from 25 to 75 mm are generally required to generate a constant shear force for shearing between geosynthetic and soil interfaces.

C-5.9 Remove the normal stress and disassemble the device at the end of the test. Carefully inspect and identify the failure surface and the area of the clamp. Failures should be consistent for all tests in order for the test data to be comparable.

C-5.10 At the end of the test, remove the soil specimen (if used) to determine the density and moisture content.

C-5.11 Repeat the procedure for a minimum of two additional normal compressive stresses.

C-5.12 Plot the test data as a graph of applied shear force *versus* horizontal displacement. For this plot,

identify the limiting value(s) of shear force. Determine the horizontal displacements for these shear forces.

C-6 CALCULATION

C-6.1 For tests using soil, calculate the initial and final water content, unit weight, and degree of saturation, if required.

C-6.2 Calculate the apparent shear stress applied to the specimen for each recorded shear force as follows:

$$T = \frac{F_s - F_{cor}}{A_c}$$

where

T = shear stress, in kPa;

F_s = shear force, in kN;

F_{cor} = correction to shear force for friction, in kN;
and

A_c = corrected area, in m².

C-6.2.1 For tests in which the area of specimen contact decreases with increased displacement, a corrected area shall be calculated. This will occur in test devices in which the stationary and travelling containers have the same overall plan dimensions. In this case, the actual contact area will decrease as a function of horizontal displacement of the traveling container. For square or rectangular containers, the corrected area is calculated for each displacement reading using the following equation:

$$A_c = A_o - (d \times W)$$

where

A_c = corrected area, in m²;

A_o = initial specimen contact area, in m²;

d = horizontal displacement of the travelling container, in m, and

W = specimen contact width in a direction perpendicular to that of shear force application, in m.

C-6.2.2 No area correction may be required for tests in which the stationary container is larger than the travelling container, provided that the horizontal displacement of the travelling container does not result in a decrease in specimen contact area.

NOTE — For devices which apply the normal stress to the interface as a constant force, for example by dead weights, any area correction applied to the shear force shall also be applied to the normal force.

C-6.3 Plot the limiting values of shear stress *versus* applied normal stress for each test conducted. Limiting values are typically at peak shear stress and at the end of the test. Other limiting values may be specified by the user. The shear stress and normal stress axes shall be drawn to the same scale.

C-6.4 Connect the data points with a straight line. Some judgment and experience may be required to construct this line, which is referred to as the strength envelope. The slope of the failure envelope is the coefficient of friction. The angle of friction is determined using the following equation:

$$d_p = \tan^{-1} (w_p)$$

where

d_p = angle of friction corresponding to the limiting shear stress, in degree, and

w_p = coefficient of friction corresponding to the limiting shear stress. Friction angle and adhesion intercept are typically reported for the peak shear stress condition.

C-6.5 Additionally, the coefficient of friction may be calculated at some condition other than peak horizontal force, such as at a specific value of shear displacement or at the end of the test. The procedure given in **C-6.4** can be used to determine a friction angle and adhesion intercept, using the shear stress and normal stress for this other condition. Parameters obtained for a condition other than peak horizontal force should be clearly defined and the condition for which they apply defined.

ANNEX D*(Foreword)***COMMITTEE COMPOSITION****Geosynthetics Sectional Committee, TX 30**

<i>Organization</i>	<i>Representative(s)</i>
The Bombay Textile Research Association, Mumbai	DR A. N. DESAI (Chairman) SHRI V. K. PATIL (<i>Alternate</i>)
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IS 16393 : 2015

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(Continued from Second Cover)

Survivability is defined as resistance to mechanical damage during road construction and initial operation. The ability of a geosynthetic to survive installation and reasonable service loads shall be assured if it is to perform as designed. Installation damage to a geotextile is a function of the following:

- a) Geotextile thickness,
- b) Compactive effort and lift thickness,
- c) Type and weight of construction equipment used for fill spreading,
- d) Grain size distribution of backfill,
- e) Angularity of backfill,
- f) Polymer used in the manufacture of geotextile, and
- g) Geotextile manufacturing process.

Geotextiles normally used for drainage application are mainly made from polyester (PET) or polypropylene (PP). PP is lighter than water, strong and very durable. PET is heavier than water, has excellent strength and creep properties, and is compatible with most common soil environments. Geotextiles are mainly of two types, namely, woven and non-woven geotextiles. Knitted and stitch bonded geotextiles are occasionally used in the manufacture of specialty products. Non-woven geotextiles are highly desirable for subsurface drainage and erosion control applications as well as for road stabilization over wet moisture sensitive soils. Out of woven geotextiles, slit film fabrics geotextiles are commonly used for sediment control, that is silt fence and road stabilization applications but are poor choices for subsurface drainage and erosion control applications. Monofilament woven geotextiles have better permeability making them suitable for certain drainage and erosion control applications. High strength multifilament woven geotextiles are primarily used in reinforcement applications.

The Committee has reviewed the provisions of the following International Standard referred in this standard and has decided that it is acceptable for use in conjunction with this standard:

<i>International Standard</i>	<i>Title</i>
ISO 10722 : 2007	Geosynthetics — Index test procedure for the evaluation of mechanical damage under repeated loading — Damage caused by granular material

The composition of the Committee responsible for the formulation of this standard is given in Annex D.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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